The Tyndall Mote. Enabling Wireless Research and Practical Sensor Application Development.

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Abstract: Wireless sensor networks are fast becoming a major technology driver, with applications seen ranging from medical and environmental monitoring to wearable sensor systems. Different application and demonstrators require specific hardware implementations. The 25mm modular stackable layer solution, developed by the AES group at the Tyndall National Institute, has proven to yield an easy solution for integration of sensors to a miniaturised communications platform enabling sensor network development and deployment. Representative wireless applications, through research collaborations throughout Europe and Ireland are presented here. A number of major applications are outlined, the development of a wearable inertial sensor system (WIMS) and a water monitoring application. Also outlined are some general WSN projects enabled by Tyndalls National Access Programme (NAP)

1. Introduction

Wireless sensor network systems are being investigated in many research institutes around the world, looking at different miniaturisation techniques, deployment scenarios, networking protocols and sensor integration mechanisms. At present the Tyndall National Institute has made available, through the National Access Programme (NAP) [1], a development system for such Wireless Sensor Networks (WSNs) called the Tyndall Mote [2]. This modular WSN development platform is currently in use in a wide range of projects due to its novel interconnect mechanism which provides for the capability of "Plug and Play" interfacing of different hardware technologies, sensor platforms, power supplies and transceivers for example

1.1 Tyndall Mote

This hardware platform is a modular 25mm x 25mm stackable system. Its modular nature lends itself to the development of a variety of layers for use in different application scenarios. These layers can be combined in an innovative plug and play fashion depending on the particular application requirements. The communication layer is comprised of a microcontroller, RF transceiver and embedded antenna. The stackable configuration (Figure 1) enables ease of connectivity between layers and makes it ideal for use as a development platform for wireless sensor networks.

Tom Pfeifer et al. (Eds.): Advances in Pervasive Computing 2006
Adjunct Proceedings of Pervasive 2006, Dublin, 7-10 May
books@OCG.at Vol. 207, ISBN 3-85403-207-2

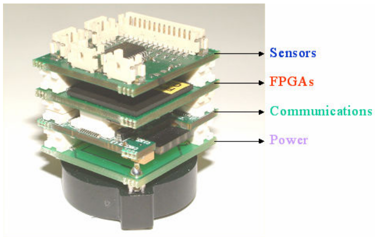

Fig 1. 25mm module stackable configuration

The transceiver/microcontroller layer was developed to provide RF communications capability between sensor nodes [3]. The layer incorporates a microcontroller driving various transceivers (standards and non standards based) operating in the 2.4GHz ISM band. The embedded microcontroller is the Atmel AVR ATmega128L, an 8-bit microcontroller with 128 Kbytes in-system programmable flash, allowing the user to develop communication protocols and sensor solutions.

2. WIMS: Wireless Inertial Measurement System - Celeritas

Much research in the area of interactive arts has been carried out in the responsive environment group at MIT Media Lab [4]. The work reported on systems using magnetic sensors for Tangible Music Interfaces [5] and processing algorithms for large groups of dancers [6] using wireless networks. CELERITAS is a collaborative project combining the wireless sensor technology of Tyndall with the software processing capabilities of Brown University, Rhode Island. The link between the two is a contemporary dancer whose main area of interest is the merging of modern day dance with modern day technology. This dancer has worked previously with a vision-based system [7] and felt that a transition to a wearable (WIMS) system may open up a new era in interactive dance. The WIMS system is designed for integration into a body suit, which is to be worn by a contemporary dancer. The dancers movements are extracted from the wearable network of sensors and processed by a high-level software system that connects to the dancer wirelessly

Eight WIMS modules are deployed around the dancer's body in the final wearable implementation. The proposed suit will have integrated 25mm connectors placed, on flexible substrates, at specified deployment locations on the body. The interconnect and power lines are to be built in to the suit with the power being provided by an innovative belt unit stacked with slim line battery packs.

Each of the nodes distributed on the dancers body is prescribed with a node address. The base station unit consists of a transmitter unit and a receiver unit. The transmitter will cycle through all eight nodes requesting the node information. The sensor nodes, on receipt of their address will reply to the receiver connected to the base station. The data will be processed accordingly. This dual node transmitter/receiver configuration will create an open channel to the processor which negates the need to switch the base station module between transmit and receive which may lead to unnecessary time lags so as to enable real time motion capture.

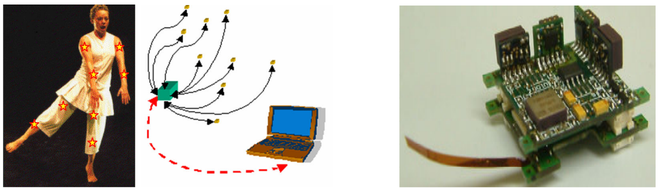

Fig 2. (a) CELERITAS Concept, (b) 25mm WIMU Module

The proposed system is designed around the Tyndall 25mm WIMU node, which is a wirelessly enabled 6 Degree of Freedom (DOF) Inertial Measurement Unit. The system consists of eight WIMU modules distributed down the trunk and at the extremities of the dancer. Each of the sensors connects to a base station, using an address driven Master/Slave request/reply protocol, for data harvesting and processing. The CELERITAS concept can be seen in Figure 2(a).

The 25mm WIMU is made up of an array of inertial sensors coupled with a high resolution Analog to Digital converter (ADC) capable of connection to the Tyndall 25mm system. The inertial sensor array consists of three single axis gyroscopes, and two dual axis accelerometers, from Analog Devices [8], and two dual axis magnetometers, HMC1052L from Honeywell [9]. The sensor array was designed with a novel 3D structure, which produces the six Degree of Freedom (DOF) functionality. The module also has a 12-bit ADC chip, from Analog Devices, handling the data conversion. This chip has a Serial Peripheral Interface (SPI), which allows easy interfacing to the ATMEL microcontroller in the transceiver section of the mote. The 3D structure, Figure 2(b), was implemented using a motherboard/daughterboard configuration. Miniature slots were drilled in the motherboard to accept the daughterboard at 90°. The motherboard was configured so the sensors would make up the relevant array to generate the 6 degrees of freedom required for the module.

3. Marine Application - SmartCoast

One area of research that has seen an increase in interest is the remote sensing of the marine environment [10]. The implementation of the Water Framework Directive [11] across the EU, and the growing international emphasis on the management of water quality is giving rise to an expanding international market for novel, miniaturised, intelligent monitoring systems for freshwater catchments and transitional and coastal waters. The small size, energy efficiency and modularity of the Tyndall Mote make it ideal for such applications. One such programme funded by Irelands Marine Institute [12] is the SmartCoast project. The goal of this project is to create an "environmental nervous system" monitoring the quality of water environments, including rivers, lakes and coastal waters. By using such a system for continuous monitoring, nitrate vulnerable zones can be protected, nutrient levels at coastal areas could be controlled, non point-sources of pollution could be mapped and river basin districts might be better protected in general. Current monitoring methods do not have the same granularity as wireless sensor networks, and so may be insufficient to identify pollution sources or environmental change.

3.1 Integration of SmartCoast Sensors to the Tyndall Mote

In the Smart Coast project a number of sensors are to be developed which include dissolved oxygen (DO), pH levels, chlorophyll and phosphate sensors, each of which will have to communicate with the Tyndall mote. To do this a programmable interface layer has been developed. This interface layer incorporates a Programmable System on Chip (PSoC) [13] device, which can be easily reconfigured through software to accept different types of sensor outputs.

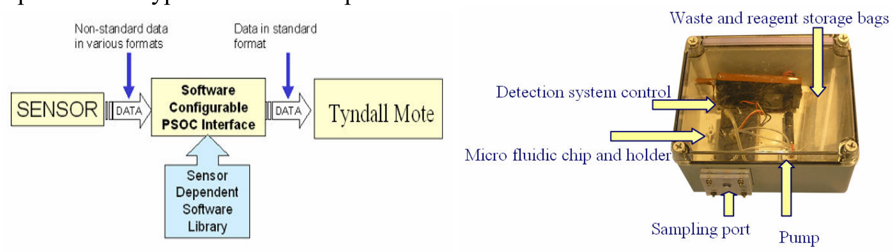

Fig 3. PSOC concept and NCSR Phosphate Sensor

One of the first sensors that is to be integrated with the Tyndall mote and PSOC is a Phosphate sensor, Figure 3, which has been developed by the National Centre for Sensor Research NCSR [14]. This sensor is based on the yellow vanadomolybdophosphoric acid method for phosphate detection. This is a simple colorimetric technique which involves the formation of vanadomolybdophosphoric acid when a phosphate-containing sample is mixed in a 1:1 ratio with an acidic reagent containing ammonium molybdate and ammonium metavanadate. The measured absorbance of the resulting yellow solution is used to determine the concentration of phosphate in the original sample.

At present a plug and play wireless sensor system is in operation in a lab based environment using temperature and DO sensors, the next phase will see the integration of the Tyndall mote with various state of the art sensors developed by the NCSR in a ruggedised system to survive in the harsh marine environment.

4. General Wireless Sensor Network Case Studies

4.1 Environmental monitoring of plants and smart spaces

Wireless sensor research in the area of environmental monitoring is experiencing explosive growth within the research community. In particular a NAP project focussing on the applications and use of wireless sensor nodes to create a sensor network for the control of plant growth conditions [15] was engaged. Currently there are sensor systems available for hardwired networks of sensors, utilising WLAN capabilities of PDA's and Laptops, in facilities like glasshouses, but they are difficult to install and require complete restructuring if additional sensors are added to the system. Tyndall's wireless sensor modules were particularly suited to enable a low cost, re-configurable solution. A schematic of the system is shown in Figure 4.

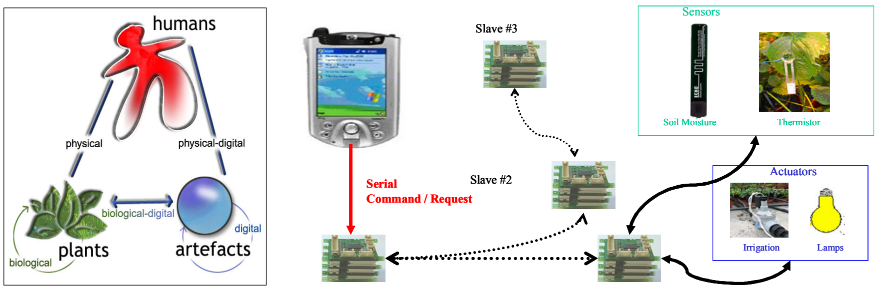

Fig. 4. Tyndall 25mm mote application, controlling plant temperature & growth conditions.

In particular a new sensor actuator layer was designed, enabling interfacing to soil moisture probes, thermistors and relays for actuating pumps and for control of leaf temperature. A "generic" sensor interface layer enables the integration of sensors to monitor temperature, humidity, light level, heat and sound, through the use of customisable analog sensor conditioning circuitry, and the full availability of the micro-controllers digital I/O ports and interfaces (e.g. I2C, SPI, UART's), . Consequently it is possible to interface to both analog and digital sensors and also to have LEDs or buzzer event alerts or other actuators implemented.

4.2 Wearable sensors and human interfacing

Wearable sensors, human interfacing and animal monitoring are experiencing significant growth, although remaining a controversial area. In particular further NAP enabled research has been conducted on 3D Graphical Software Interface for an electronic glove and Human Computer Interface (HCR) [16]. Specifically the research has focused upon the representation of data from a wireless sensor enabled glove, developed by the Tyndall Institute AES group, and the use of this data to manipulate virtual objects on a PC screen. In collaboration with the AES team, a 3D graphical interactive interface (GUI) was developed to demonstrate the functionality of the electronic glove, by moving virtual objects on the computer screen, of which the prototype development cycle is depicted in Figure 5. The hardware realisation of the glove involved the design and fabrication of a flexible PCB, integration of bend sensors and the use of a 2-axis accelerometer.

Fig. 5. 25mm Tyndall wireless sensor enabled glove prototype & GUI development cycle.

5. Conclusions

The explosive growth in the use of sensor systems integrating hardware and software platforms to provide control of wireless networks has led to extensive research into the development and deployment of wireless systems of various configurations. The Tyndall WSN development platform has been developed to enable Wireless Sensor Research in Ireland and throughout the world. Selections of WSN project applications, facilitated by the expertise resident in the Ambient Electronic Systems (AES) group within the Tyndall Institute, are presented.

6. Acknowledgements

I would like to acknowledge the support of the Marine Institute, NCSR and enterprise Ireland for helping this body of work progress. I would also like to acknowledge Science foundation Ireland (SFI) and in particular Tyndalls National Access Program (NAP) for funding the collaborative research proposals. Special acknowledgement also goes to the NAP proposal research partners for their contributions and also to all members of the AES team at Tyndall for their support during the projects.

7. References

[1] National Access Program (SFI), http://www.tyndall.ie/nap/vt.html
[2] John Barton, Brendan O'Flynn, Stephen Bellis, Andrew Lynch, Micheal Morris, Sean Cian O'Mathuna, "A Miniaturised Modular Platform For Wireless Sensor Networks"; 2005 European Conference on Circuit Theory and Design, 29 Aug-1 Sep, 2005, Cork, Ireland.
[3] O'Flynn B, et Al, "A 3-D Miniaturised Programmable Transceiver", Microelectronics International, Vol. 22, No. 2, 2005, pp. 8-12,
[4] http://www.responsive
[5] Paradiso J et Al, "Tangible Music Interfaces Using Passive Magnetic Tags", 2001, ACM CHI Conference - Special Workshop on New Interfaces for Musical Expression.
[6] Feldmeier M, Paradiso J A, "Ultra Low Cost Wireless Sensors for Musical Interaction for very large groups", 2001, UbicompWorkshop on Designing Ubiquitous Computing Games
[7] Winkler T, Cummings C, "Live Video and Sound Processing for Dance", 2003, Video, Technology and Performance Festival, Brown University
[8] http://www.analog.com/
[9] http://www.ssec.honeywell.com/magnetic/products.html
[10] Smith, Kenneth D. (Naval Air Warfare Cent);"Remote sensing instruments for water monitoring", National Environmental Journal, v 5, n 5, Sep-Oct, 1995, p 27-28
[11] http://europa.eu.int/comm/environment/water/water-framework/index_en.html
[12] http://www.marine.ie
[13] http://www.cypress.com/
[14] http://www.ncsr.ie/
[15] www.ireland.com/newspaper/science/2005/0505/4046882961ftsc5plants.html
[16] Brendan O'Flynn et Al, "Implementation of a Wearable Wireless Sensor System "28th IMAPS – POLAND CHAPTER CONF. 2005, September 19 - 22, 2005, Sept, 2005.